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RESEARCH MEMORANDUM

A LOW-SPEED INVESTIGATION OF A HIGH-LIFT LATERAL-CONTROL DEVICE CONSISTING OF A SPOILER-SLOT-DEFLECTOR AND A TRAILING-EDGE FLAP ON A TAPERED 45° SWEPTBACK WING

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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A LOW-SPEED INVESTIGATION OF A HIGH-LIFT LATERAL-CONTROL DEVICE CONSISTING OF A SPOILER-SLOT-DEFLECTOR AND A TRAILING-EDGE FLAP ON A TAPERED 45° SWEPTBACK WING

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SUMMARY

An investigation has been made in the Langley 300 MPH 7- by 10-foot tunnel to determine the aerodynamic characteristics of a spoiler-slot-deflector configuration in combination with a trailing-edge 29-percent-chord high-lift flap extending from the 14- to the 67-percent-semispan station. The wing has a sweepback of 45° at the quarter-chord line, an aspect ratio of 4, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the plane of symmetry. Additional tests were made with the flap neutral to evaluate the effects of deflector projection on the characteristics of the wing equipped with a spoiler-slot-deflector configuration having the same span and spanwise position as the spoiler and deflector had with the flap deflected.

The trends of the curves of angle of attack, drag, and pitching moment with lift coefficient for the high-lift configuration (flap deflected 70° with the spoiler and deflector in neutral position) are similar to those obtained in NACA Research Memorandum L56A10 on a single slotted flap. The spoiler-slot-deflector configuration on the wing with the flap deflected 70° gives more control effectiveness than the spoiler configuration (deflector neutral) for the same spoiler projection. The spoiler-slot-deflector configuration on the plain wing shows fairly good rolling effectiveness for deflector-to-spoiler projection ratios from 0.50 to 1.00. However, the spoiler-slot-deflector configuration having a deflector-to-spoiler projection ratio of 0.75 gives somewhat better rolling effectiveness when the entire angle-of-attack range is considered.

[redacted]

INTRODUCTION

Recent investigations of spoiler-type controls suitable for use on high-speed thin-wing configurations have shown that the spoiler-slot-deflector has certain advantages over the flap-type spoiler, such as lower hinge moments and more effectiveness at high angles of attack. (For example, see ref. 1.) The spoiler-slot-deflector has also been shown to have low twisting moments which has been associated with spoiler-type controls in general. (See ref. 2.)

In order to make use of the wing area behind the spoiler-slot-deflector, it was proposed by North American Aviation, Inc., that this device be used in combination with a trailing-edge high-lift flap. If the spoiler, slot, and deflector were located in such a manner that the slot would be at the nose of the flap, this arrangement could be used for lateral control as well as function as a slotted flap for high lift. An investigation of such an arrangement was conducted in the Langley 300 MPH 7- by 10-foot tunnel on a 6-percent-thick wing swept back 45° with an aspect ratio of 4 and a taper ratio of 0.6 having an inboard trailing-edge flap hinged at the 0.71-chord line and extending from 0.14 semispan to 0.67 semispan.

In addition, a few tests were made with the flap neutral to evaluate the effects of deflector projection on the characteristics of the wing equipped with a spoiler-slot-deflector configuration having the same span and spanwise position as the spoiler and deflector had with the flap deflected.

COEFFICIENTS AND SYMBOLS

The forces and moments on the wing are presented about the wind axes which, for the condition of these tests (zero yaw), correspond to the stability axes. The axes intersect at the plane of symmetry and the chord plane of the model at the 25-percent-mean-aerodynamic-chord station as shown in figure 1.

C_L lift coefficient, $\frac{\text{Twice lift of semispan model}}{qS}$

C_D drag coefficient, $\frac{\text{Twice drag of semispan model}}{qS}$

C_m pitching-moment coefficient referred to $0.25\bar{c}$, $\frac{\text{Twice pitching moment of semispan}}{qS\bar{c}}$

C_l rolling-moment coefficient resulting from control projection at plane of symmetry, $\frac{\text{Rolling moment of semispan model}}{qSb}$

C_n yawing-moment coefficient resulting from control projection, $\frac{\text{Yawing moment of semispan model}}{qSb}$

q dynamic pressure, lb/sq ft, $\frac{1}{2}\rho V^2$

S twice wing area of semispan model, 8.00 sq ft

b twice span of semispan model, 5.66 ft

$\bar{c}$ mean aerodynamic chord of wing, 1.44 ft

c local wing chord, ft

ρ mass density of air, slugs/cu ft

V free-stream air velocity, ft/sec

A aspect ratio, b^2/S

R Reynolds number based on $\bar{c}$

α angle of attack, deg

δ_s spoiler projection, fraction of wing chord from neutral position (see fig. 2)

δ_d deflector projection, fraction of wing chord from neutral position (see fig. 2)

δ_f flap deflection, deg

δ_d/δ_s deflector-to-spoiler projection ratio

MODEL AND APPARATUS

The semispan-sweptback-wing model was mounted vertically in the Langley 300 MPH 7- by 10-foot tunnel with the ceiling serving as a reflection plane. The model was mounted on the balance system in such a manner that all forces and moments acting on it could be measured. The wing had 45° of sweepback of the quarter-chord line, an aspect ratio of 4, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the plane of symmetry. A plan view and tabulated wing data are presented in figure 1.

The model was equipped with a spoiler-slot-deflector and an inboard trailing-edge-flap arrangement as shown in figure 2. The flap was hinged along the 0.71-chord line and extended from $0.14b/2$ to $0.67b/2$. The spoiler and deflectors used in this investigation were made from 3/32-inch steel sheet. The spoiler had a chord of $0.10c$, was hinged along the 64-percent-chord line, and extended over the same span as the flap. For the configuration with the flap deflected 70° and for the plain-wing configurations, the deflector was of the same dimensions as the spoiler. The deflector was hinged on the lower wing surface along the 71-percent-chord line for the configuration with the flap deflected 70° and along the 74-percent-chord line for the plain-wing configuration.

TESTS

The tests were run at an average dynamic pressure of 100 pounds per square foot, which corresponds to a Mach number of 0.26 and a Reynolds number of 2.4×10^6, based on the wing mean aerodynamic chord of 1.44 feet.

Most of the tests were run through an angle-of-attack range from -4° to 26°. Tests were made with the spoiler-slot-deflector configuration in combination with the flap deflected 70°. Tests were also made with the spoiler-slot-deflector on the plain wing (flap undeflected) at three spoiler projections for several deflector projections.

CORRECTIONS

Jet-boundary corrections, obtained from methods outlined in reference 3, have been applied to the angle-of-attack, the drag-coefficient, and the pitching-moment-coefficient data. Blockage corrections, as determined from reference 4 to account for the constriction of the model on the tunnel free-stream flow, have been applied to the data. No reflection-plane corrections have been applied to the rolling-moment coefficients.

RESULTS AND DISCUSSION

Results of this investigation are presented graphically in figures 3 to 7. The aerodynamic characteristics of the plain wing (flaps neutral) are presented in these figures for reference only and will not be discussed.

Aerodynamic Characteristics of the Spoiler-Slot-Deflector in Conjunction With the Flap

The longitudinal and lateral control characteristics for the spoiler-slot-deflector in conjunction with the flap deflected 70° are presented in figure 3. The increment of lift at zero angle of attack resulting from the high-lift configuration (the flap deflected 70° with a 0.005c gap between the spoiler trailing edge and the nose of the flap and a 0.03c gap between the deflector leading edge and the lower wing surface, the neutral position for the high-lift configuration) was 0.57 (fig. 3). Several preliminary unpublished tests were run to determine this neutral position for the spoiler and deflector (based on lift characteristics). The plain wing reached maximum lift at an angle of attack of 24°, whereas the high-lift configuration reached the same lift coefficient at an angle of attack of 12°. The drag coefficients for the high-lift configuration were increased for lift coefficients up to 0.7; above this lift coefficient, the results show a decrease in drag coefficient for a given lift coefficient. The variation of the curves of the pitching-moment coefficient with lift coefficient (fig. 3) shows a region of instability for the plain wing at a lift coefficient of about 0.58, whereas the high-lift configuration was stable up to near the stall. However, this configuration would possibly necessitate some change in trim when deflected.

The trends of the curves of angle of attack, drag, and pitching-moment coefficients with lift coefficient shown in figure 3 for the high-lift device of this investigation are similar to those trends shown in reference 5 for a single slotted flap (rear slot sealed in a double-slotted-flap configuration) on a 45° sweptback wing. The lift effectiveness of the high-lift configuration of this investigation is about what is expected for a single slotted flap with the same wing plan form.

With the flap deflected 70°, projection of the spoiler (deflector neutral) or the spoiler-slot-deflector configuration (deflector-to-spoiler projection ratio (δ_d/δ_s) equal to 0.75) generally resulted in a decrease in lift coefficient throughout the lift-coefficient range (fig. 3). With an increase in projection of these controls, the drag coefficient generally increased throughout the lift-coefficient range. Although the slopes of the curves of pitching-moment coefficient with lift coefficient were generally unchanged by projection of these controls, the unstable region experienced by the high-lift configuration occurred at a lower lift coefficient with increased control projection. Increasing the projection of the spoiler or the spoiler-slot-deflector configuration generally resulted in an increase in rolling-moment coefficient. However, the spoiler-slot-deflector configuration (δ_d/δ_s of 0.75) gave more control effectiveness than the spoiler configuration (deflector neutral) for the same spoiler projection. With increasing projection of either of the controls, the yawing-moment coefficients generally became more positive at angles of attack below about 12°.

Effect of Deflector Projection on the Aerodynamic Characteristics of a Spoiler-Slot-Deflector on the Plain Wing

The effect of deflector projection on the aerodynamic characteristics of a spoiler-slot-deflector with spoiler projections of 1, 4, and 6 percent of the wing chord are presented in figures 4, 5, and 6, respectively. Increasing the deflector projection at a given spoiler projection generally resulted in a decrease in lift coefficient, an increase in drag coefficient, a positive increment in yawing-moment coefficient, and a positive increment in pitching-moment coefficient. However, the static longitudinal stability was generally unaffected by increase in deflector projection. An increase in deflector projection generally resulted in an increase in the rolling-moment effectiveness for all deflector projections investigated.

A summary of the rolling-moment coefficients resulting from projection of a spoiler-slot-deflector configuration having deflector-to-spoiler projection ratios of 0.50, 0.75, and 1.00 obtained from figures 4 to 6 are shown in figure 7 for several spoiler projections.

The results shown in figure 7 indicate that although the spoiler-slot-deflector configuration shows fairly good rolling effectiveness for all deflector-to-spoiler projection ratios tested, the spoiler-slot-deflector configuration having a deflector-to-spoiler projection ratio of 0.75 gave somewhat better rolling effectiveness when the entire angle-of-attack range is considered.

CONCLUSIONS

An investigation was made in the Langley 300 MPH 7- by 10-foot tunnel to determine the aerodynamic characteristics of a spoiler-slot-deflector configuration in combination with a trailing-edge high-lift flap. The wing had a sweepback of 45° at the quarter-chord line, an aspect ratio of 4, a taper ratio of 0.6, and an NACA 65A006 airfoil section parallel to the plane of symmetry. Additional tests were made with the flap neutral to evaluate the effects of deflector projection on the characteristics of the wing equipped with a spoiler-slot-deflector configuration having the same span and spanwise position as the spoiler and deflector had with the flap deflected. The results of the investigation led to the following conclusions:

1. The trends of the curves of angle of attack, drag, and pitching moment with lift coefficient for the high-lift configuration of this investigation (flap deflected to 70° with the spoiler, slot, and deflector in neutral position) are similar to those obtained in NACA Research Memorandum L56A10 on a single slotted flap.

2. Increasing the projection of either the spoiler configuration (deflector neutral) or the spoiler-slot-deflector configuration (deflector-to-spoiler projection ratio (δ_d/δ_s) equal to 0.75) with the flap deflected 70° generally resulted in an increased rolling moment. However, the spoiler-slot-deflector configuration gave more control effectiveness than the spoiler configuration for the same control projection.

3. The spoiler-slot-deflector on the plain-wing configuration showed fairly good rolling effectiveness for deflector-to-spoiler projection ratios from 0.50 to 1.00. However, the spoiler-slot-deflector configuration having a deflector-to-spoiler projection ratio of 0.75 gave somewhat better rolling effectivenss when the entire angle-of-attack range was considered.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 13, 1956.

REFERENCES

1. Lowry, John G.: Data on Spoiler-Type Ailerons. NACA RM L53I24a, 1953.

2. Hammond, Alexander D.: Loads on Wings Due to Spoilers at Subsonic and Transonic Speeds. NACA RM L55E17a, 1955.

3. Polhamus, Edward C.: Jet-Boundary-Induced-Upwash Velocities for Swept Reflection-Plane Models Mounted Vertically in 7- by 10-Foot, Closed, Rectangular Wind Tunnels. NACA TN 1752, 1948.

4. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)

5. Naeseth, Rodger L.: Low-Speed Longitudinal Aerodynamic Characteristics of a 45° Sweptback Wing With Double Slotted Flaps. NACA RM L56A10, 1956.

TABULATED WING DATA

Sweep of quarter-chord line, deg .	45
Aspect ratio	4.0
Taper ratio	0.6
Wing area (twice semispan), sq ft	8.0
Airfoil section (parallel to plane of symmetry)	NACA 65A006

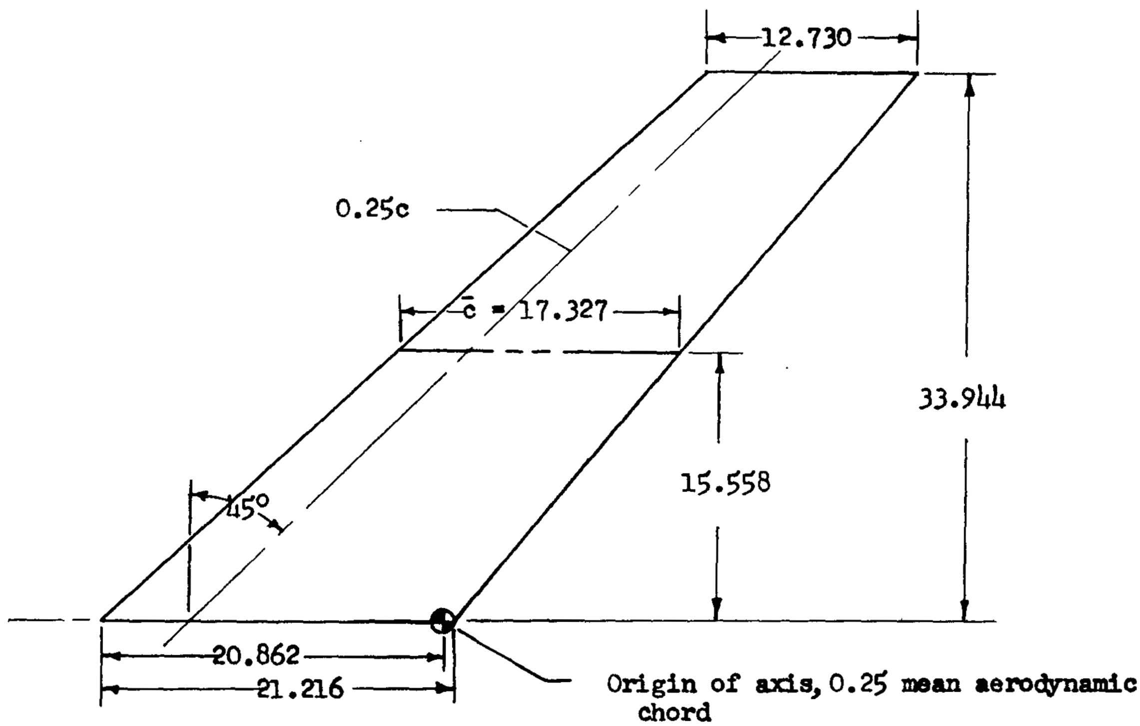


Figure 1.- Geometric characteristics of 45° sweptback semispan wing model. (All dimensions are in inches unless otherwise noted.)

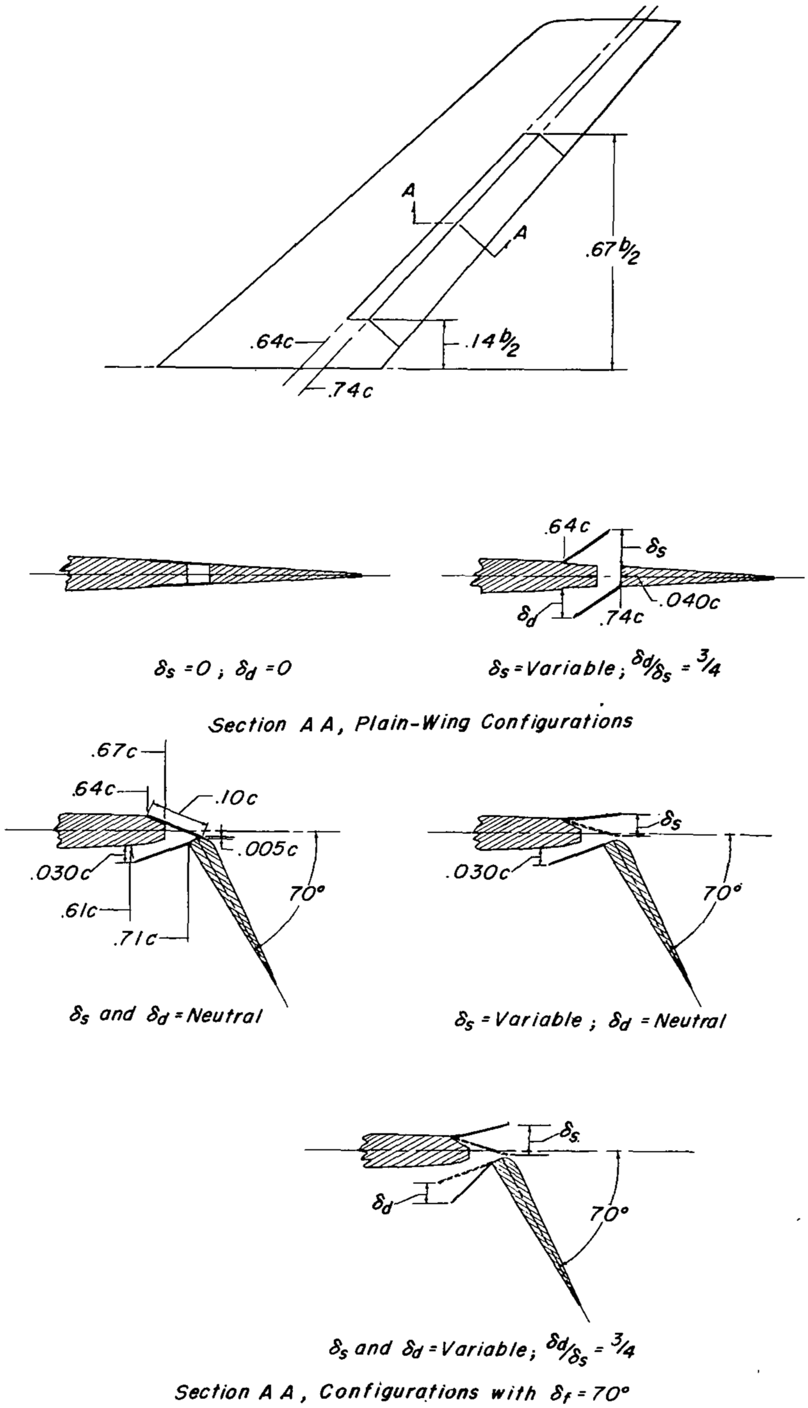
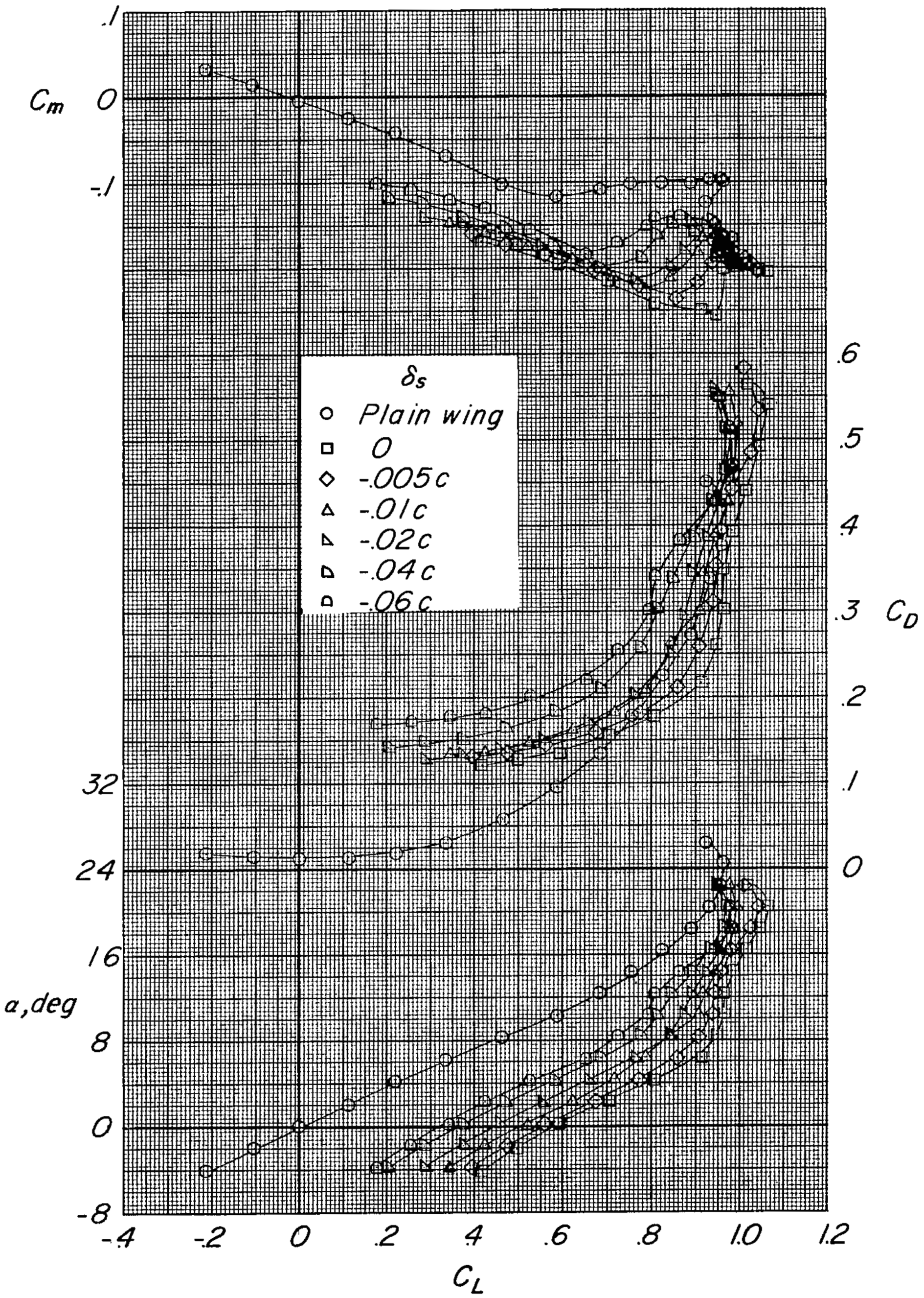
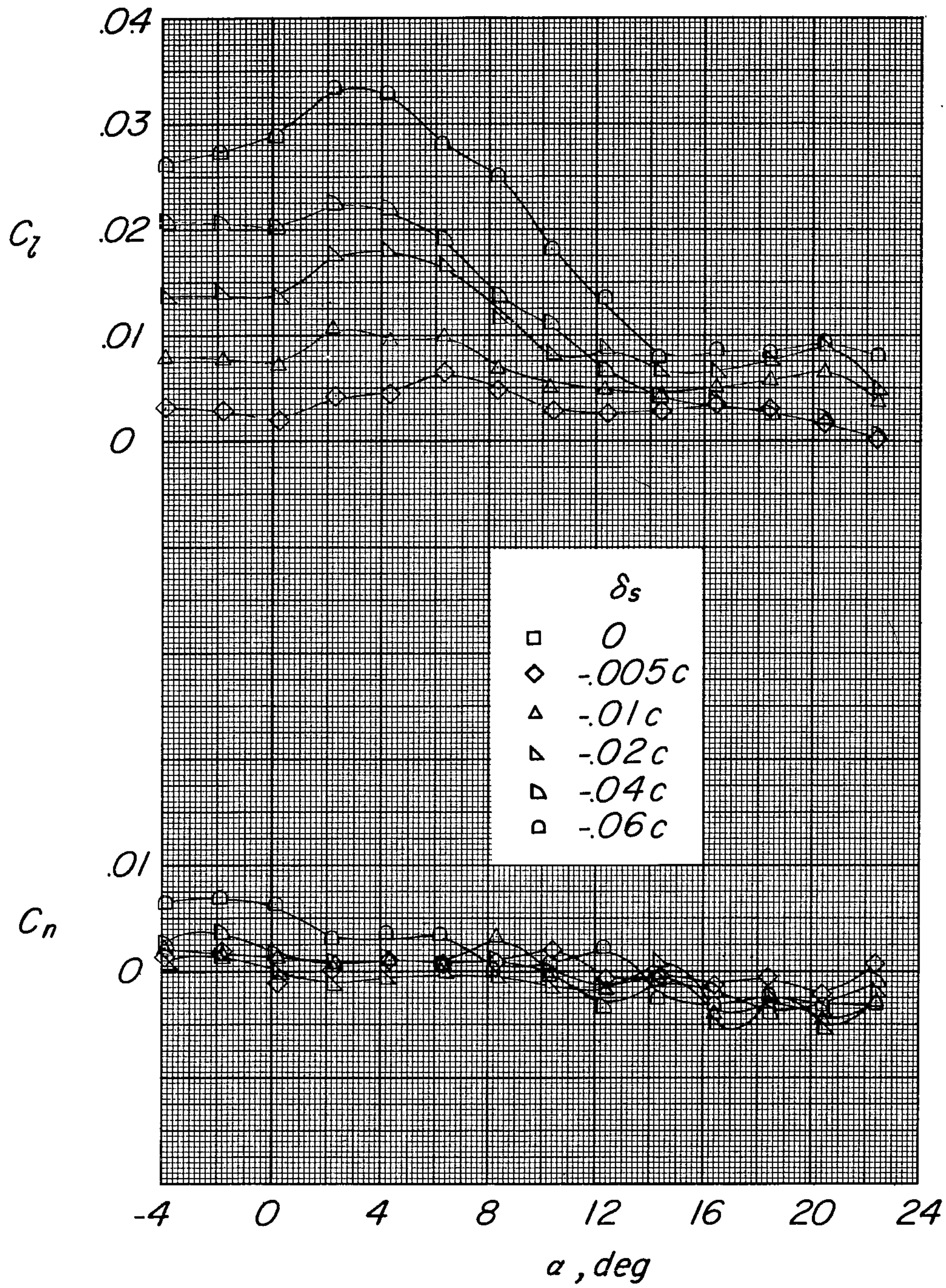


Figure 2.- Details of spoiler-slot-deflector and flap configurations.



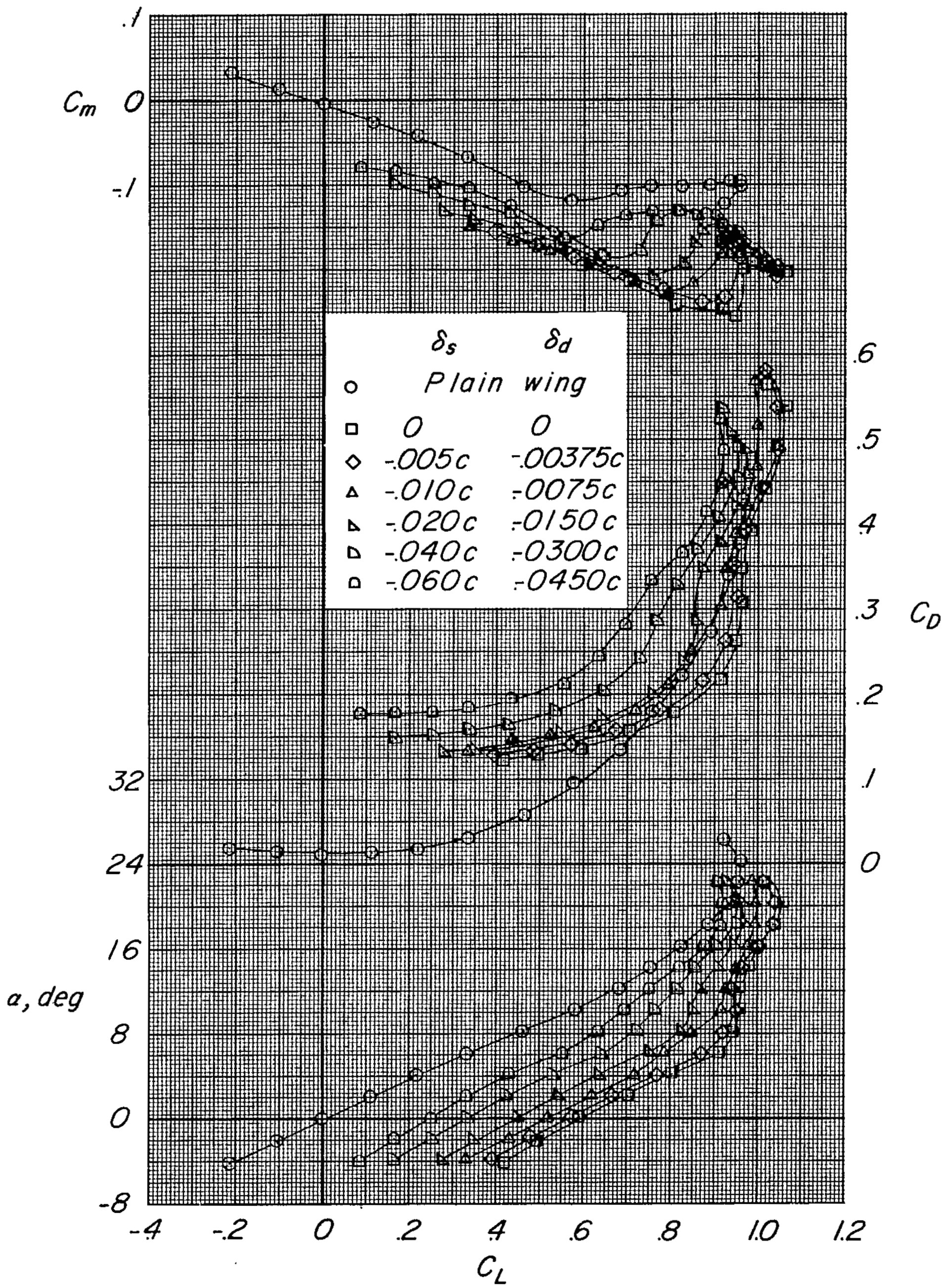
(a) Spoiler variable, deflector neutral.

Figure 3.- Variation of the aerodynamic characteristics of the wing with the flap deflected 70°.



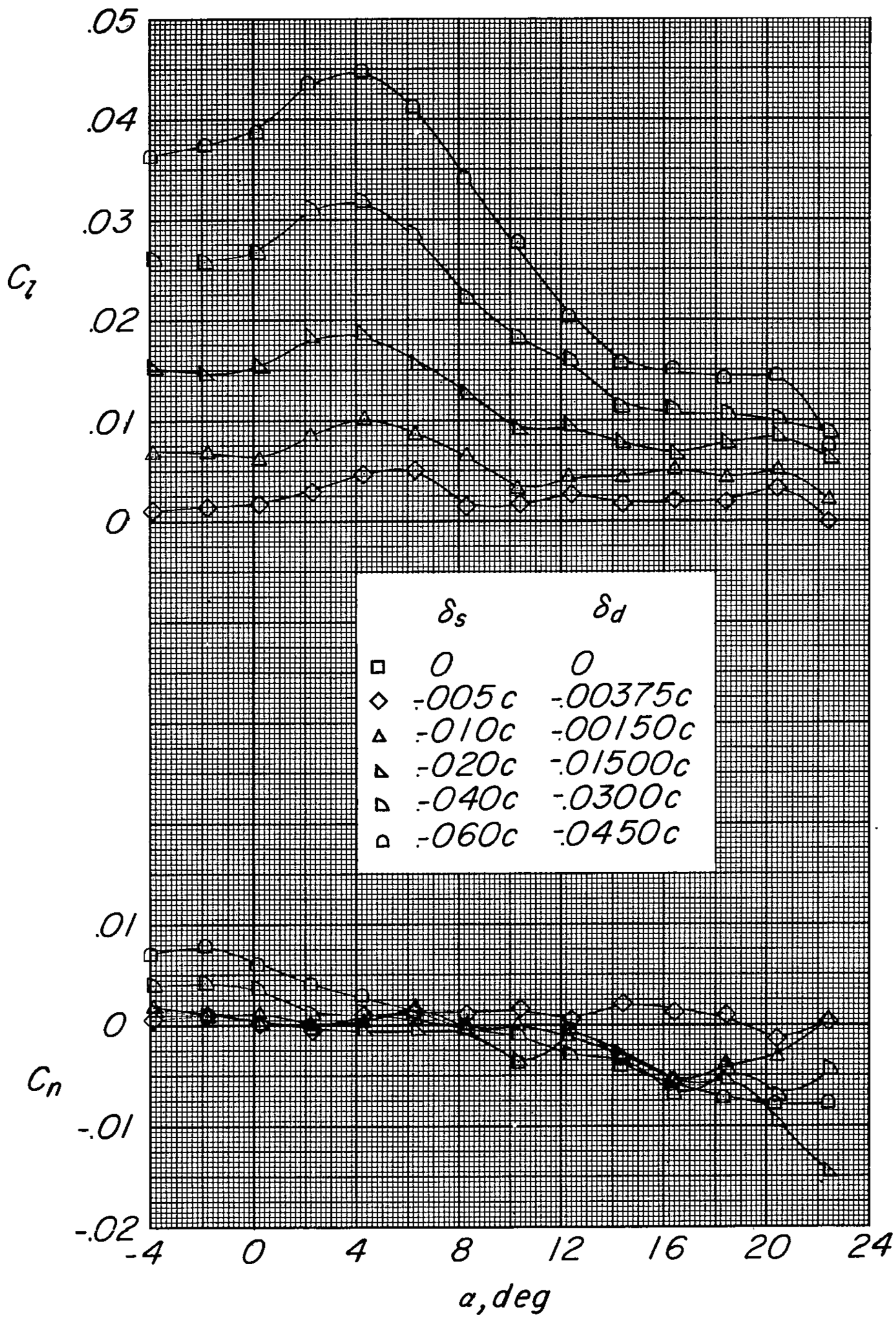
(a) Concluded.

Figure 3.- Continued.



(b) Spoiler variable, deflector variable $\left(\frac{\delta_d}{\delta_s} = 0.75\right)$.

Figure 3.- Continued.



(b) Concluded.

Figure 3.- Concluded.

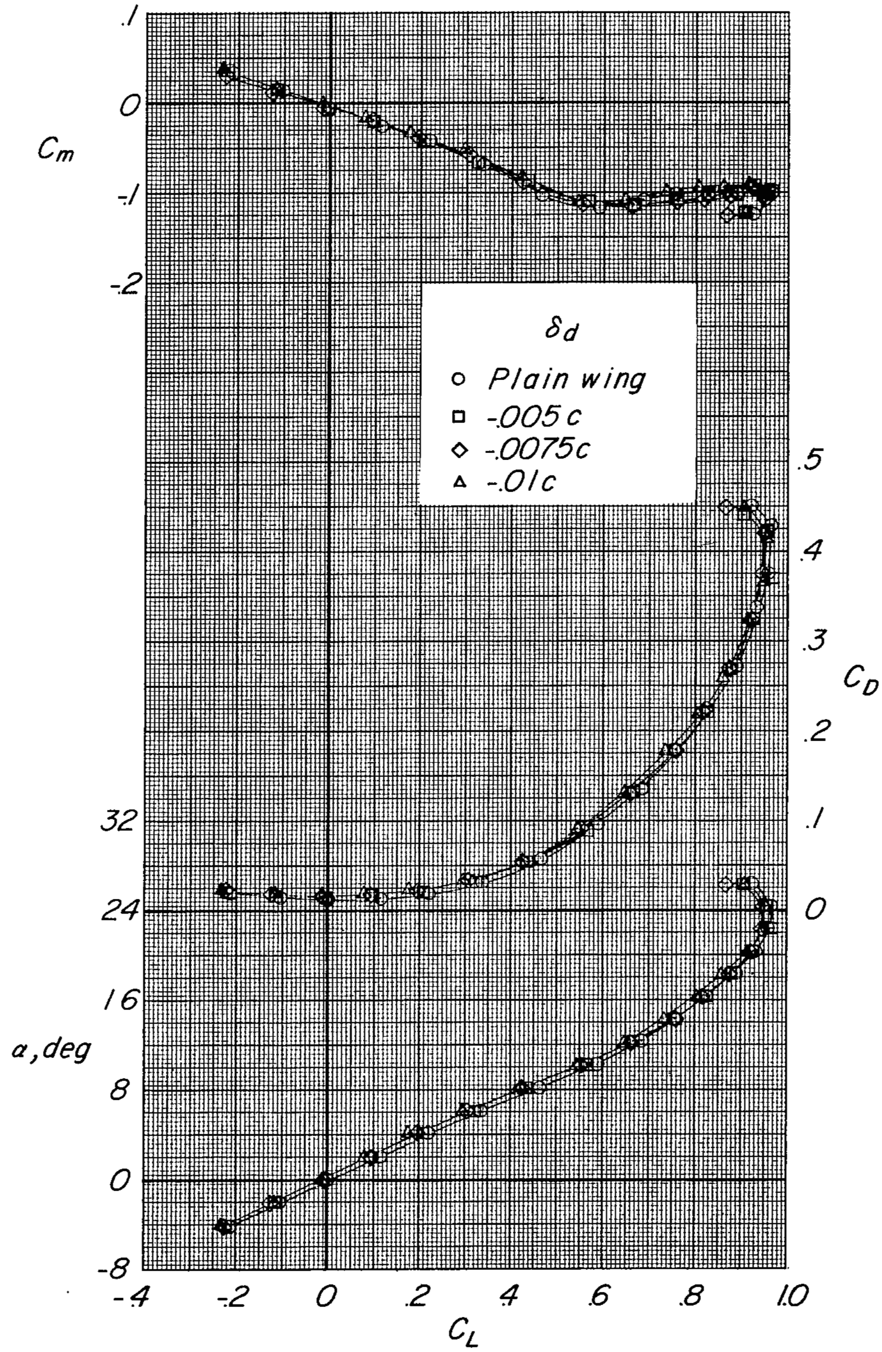


Figure 4.- Aerodynamic characteristics of the plain wing equipped with spoiler-slot deflector having a spoiler projection of -0.01c and a constant slot size of 0.04c with various deflector projections.

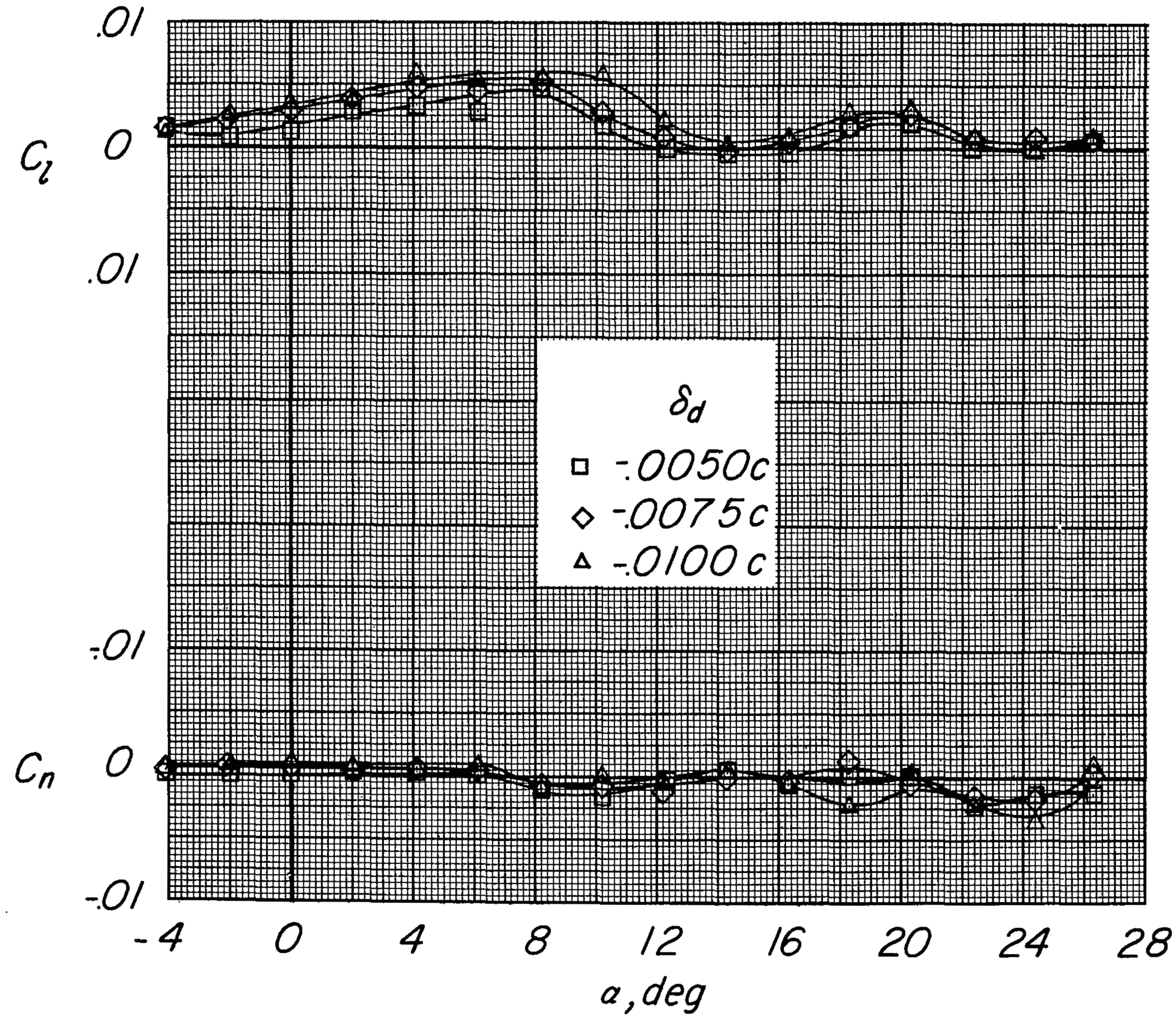


Figure 4.- Concluded.

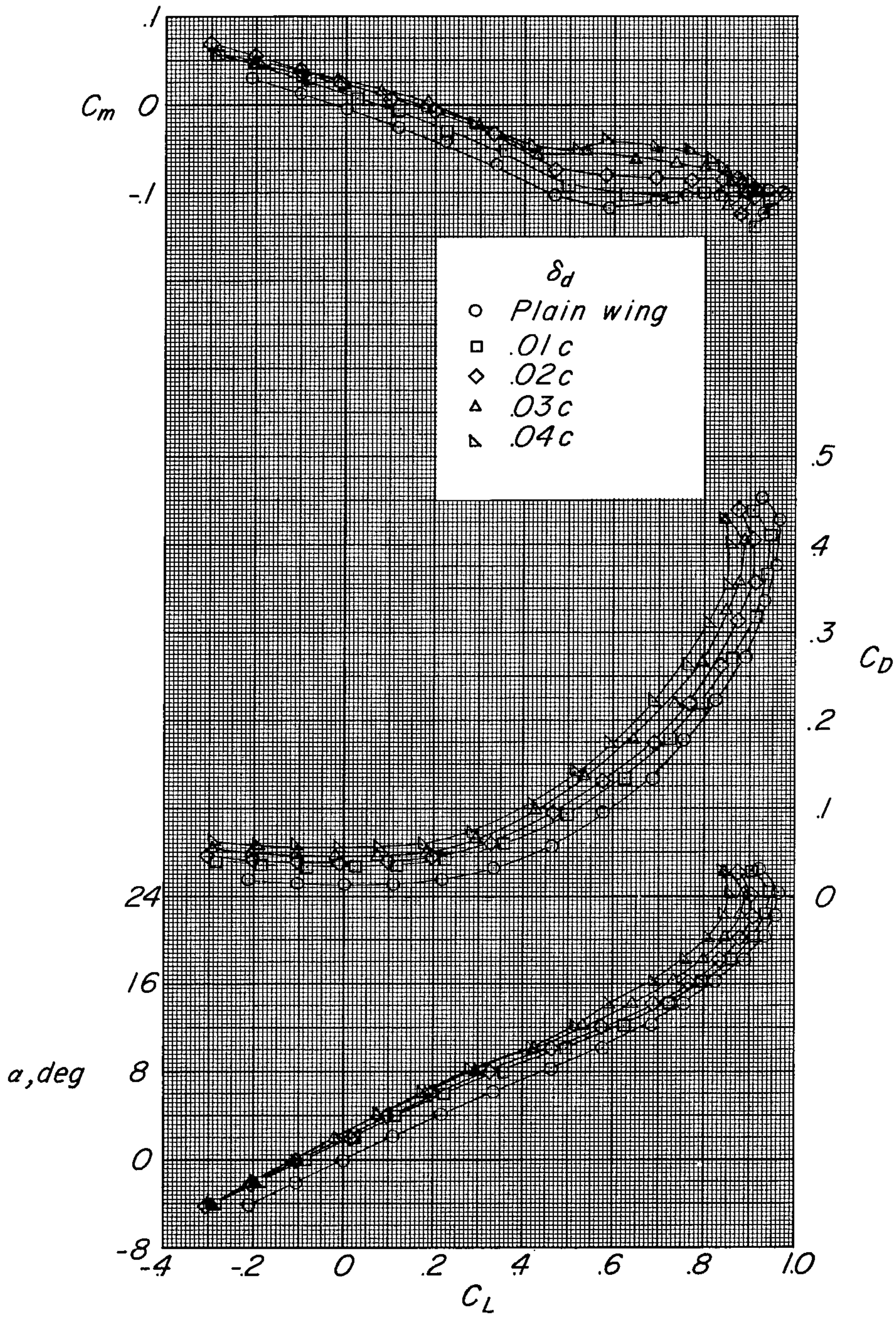


Figure 5.- Aerodynamic characteristics of the plain wing equipped with spoiler-slot deflector having a spoiler projection of -0.04c and a constant slot size of 0.04c with various deflector projections.

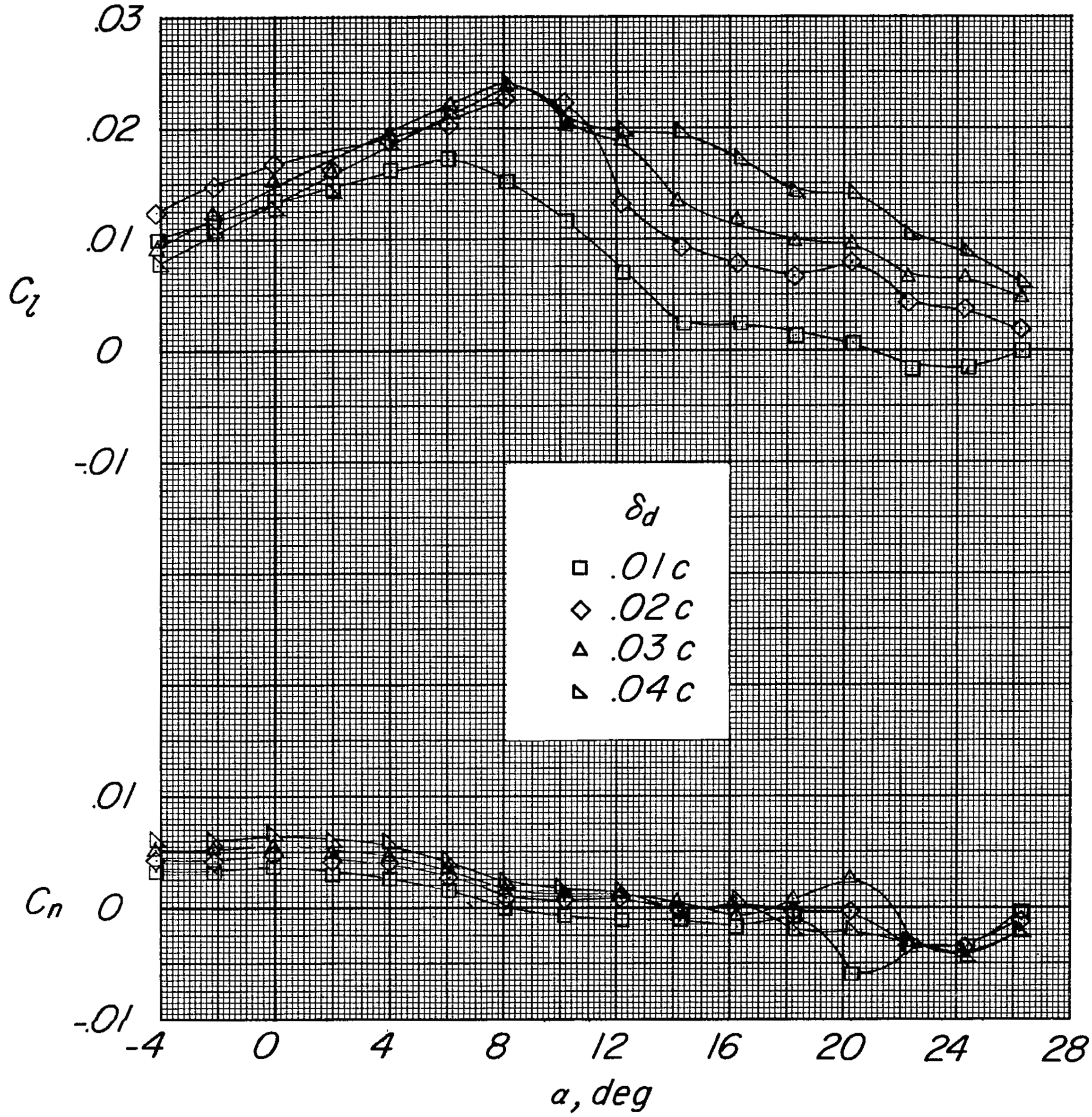


Figure 5.- Concluded.

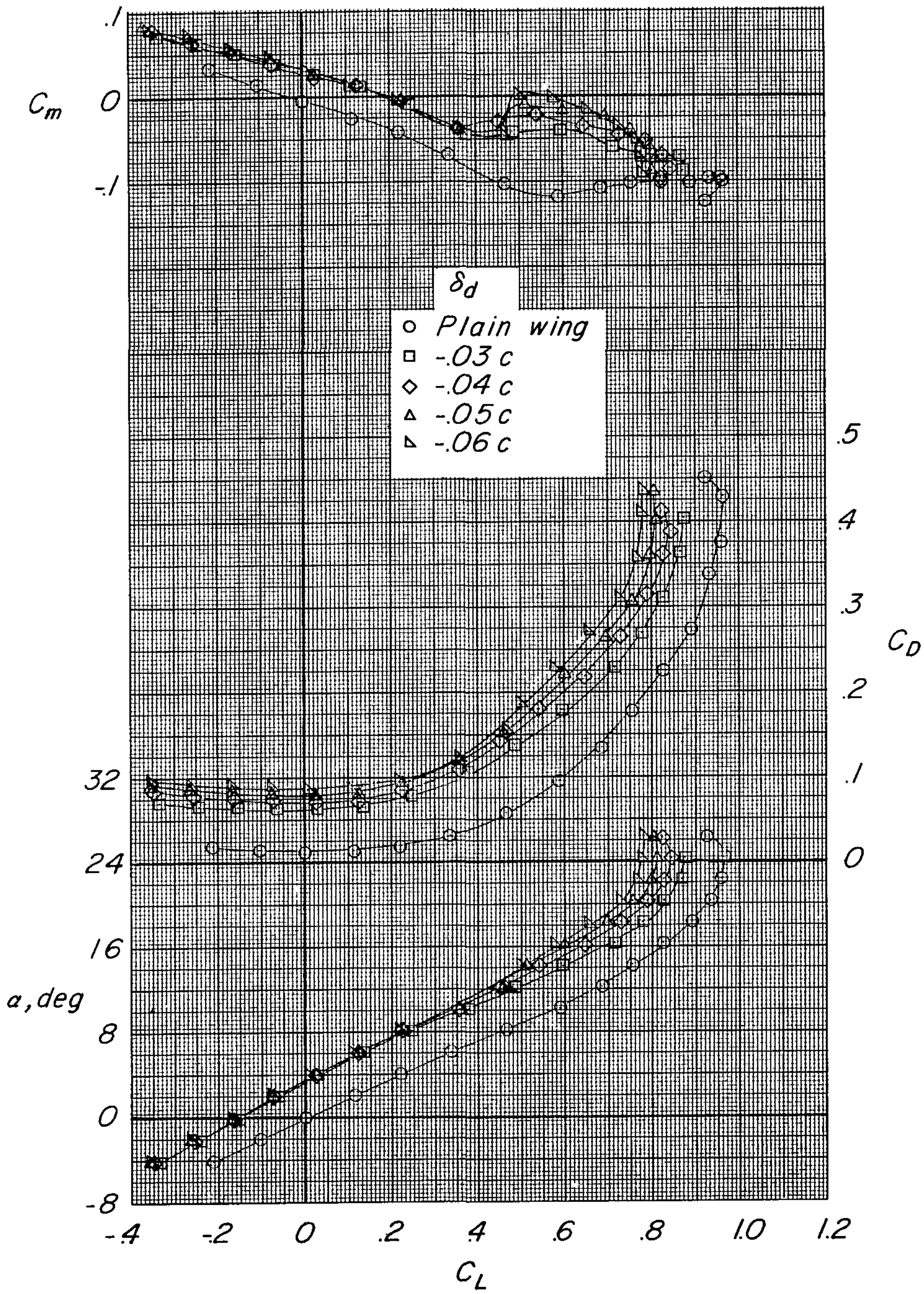


Figure 6.- Aerodynamic characteristics of the plain wing equipped with a spoiler-slot deflector having spoiler projection of -0.06c and a constant slot size of 0.04c with various deflector projections.

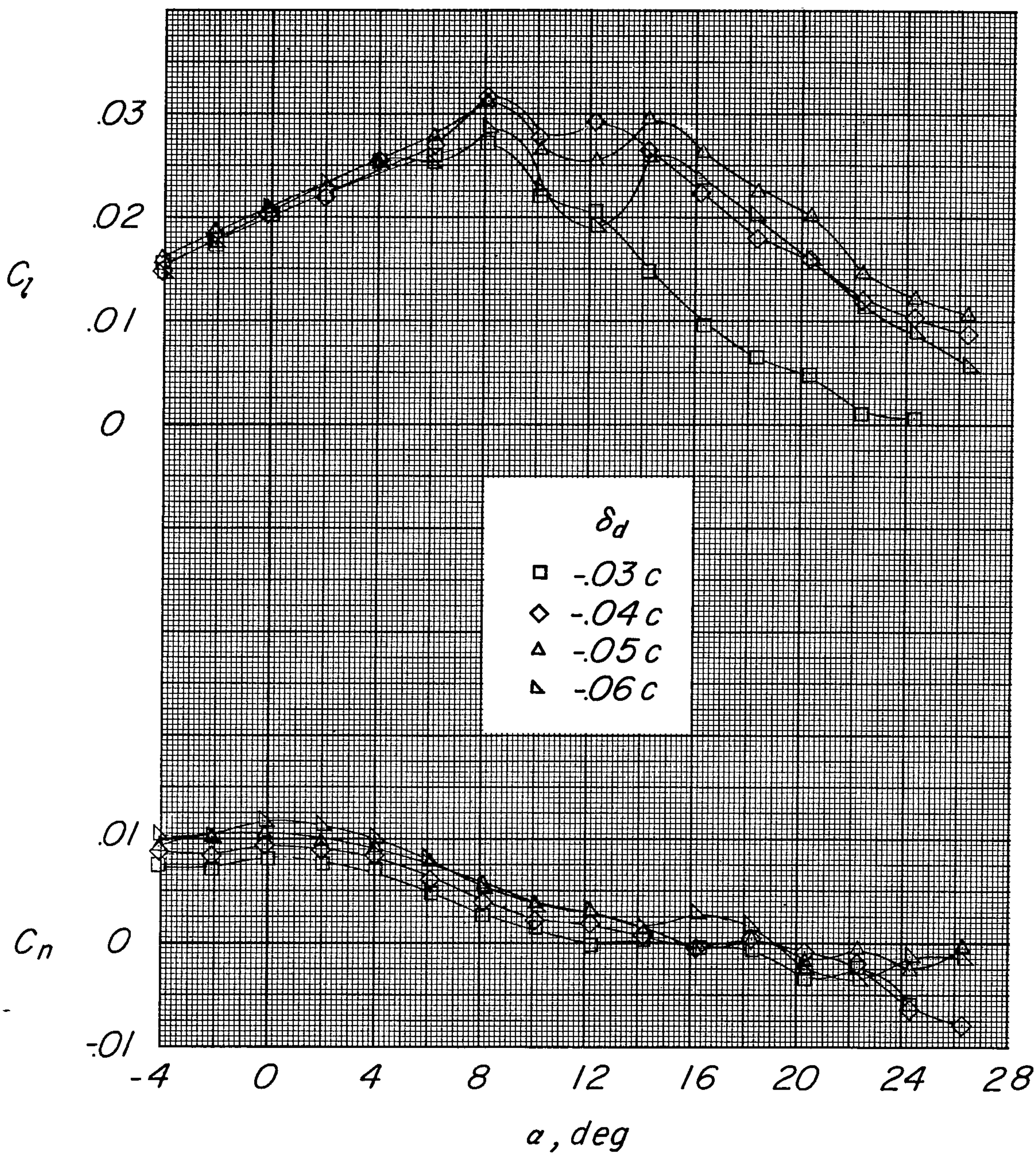


Figure 6.- Concluded.

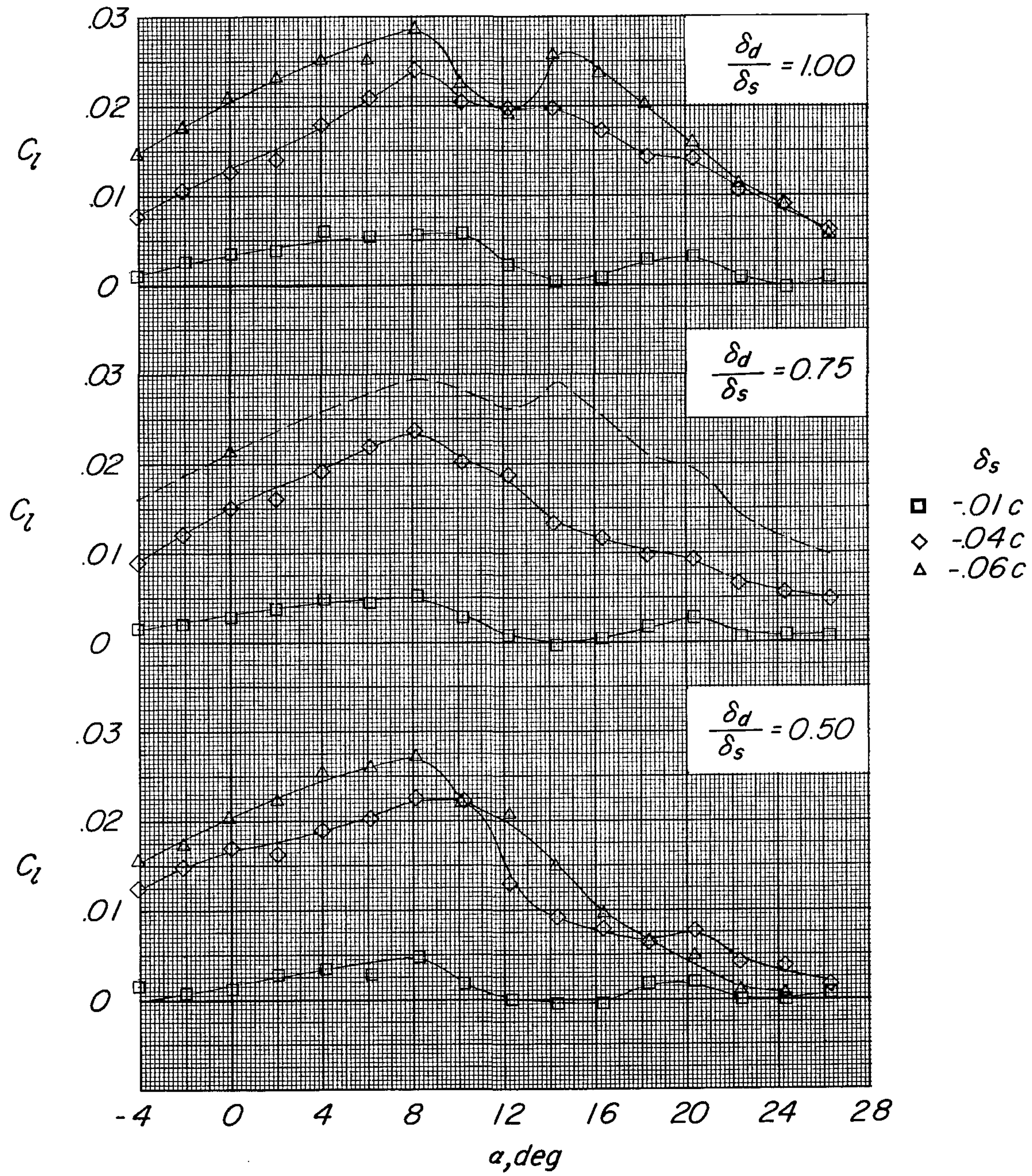


Figure 7.- Variation of rolling-moment coefficient with angle of attack for the plain wing equipped with spoiler-slot-deflector configurations having a slot size of 0.04c for various spoiler projections. (Dashed curve represents data obtained from cross plots of fig. 6.)